CLAIMS

1. Apparatus for providing an enclosure in locations of elevated pressure, the apparatus comprising:

an inner housing comprising an inner housing body and two opposing inner housing ends;

an outer housing comprising an outer housing body and two opposing outer housing ends;

the inner housing being disposed fully within the outer housing, the inner and outer housings defining an annular cavity therebetween; and

a structural filler within the cavity extending between the outer housing and the inner housing, the structural filler comprising a plurality of spaced apart structural members for transferring stress between spaced apart regions of the inner surface of the outer housing to corresponding spaced apart regions of the outer surface of the inner housing, the structural members occupying less than 60 % of the volume of the cavity occupied by the structural filler.

2. Apparatus according to claim 1, wherein the structural members occupy less than 50% of the volume of the cavity occupied by the structural filler.

3. Apparatus according to claim 2, wherein the structural members occupy less than 25% of the volume of the cavity occupied by the structural filler.

4. Apparatus according to any preceding claim, wherein the structural members extend circumferentially within the cavity.

5. Apparatus according to any of claims 1 to 3, wherein the structural members extend at an angle to the longitudinal axis of the apparatus.

6. Apparatus according to claim 5, wherein the structural members comprise a honeycomb material.

7. Apparatus according to claim 6, wherein the honeycomb is metal or a polymer.

8. Apparatus according to claim 7, wherein the honeycomb is aluminium.

9. Apparatus according to claim 7, wherein the honeycomb is nylon.

10. Apparatus according to any of claims 1 to 5, wherein the structural members are of an I-beam configuration.

11. Apparatus according to any of claims 1 to 5, wherein the structural members are tubular.

12. Apparatus according to claim 11, wherein the structural members extend helically around the longitudinal axis within the cavity.

13. Apparatus according to either of claims 11 or 12, wherein the structural members are circular in cross-section.

14. Apparatus according to claim 13, wherein the structural members are tubular having a circular cross-section and contain a pressurized fluid in order to pre-stress the structural member to resist compressive hydrostatic forces.

15. Apparatus for providing an enclosure in locations of elevated pressure, the apparatus comprising:

an inner housing comprising an inner housing body and two opposing inner housing ends;

an outer housing comprising an outer housing body and two opposing outer housing ends;

the inner housing being disposed fully within the outer housing, the inner and outer housings defining an annular cavity therebetween; and

a structural filler within the cavity extending between the outer housing and the inner housing, the structural filler comprising a continuous, substantially void-free resinous phase.

16. Apparatus according to claim 15, wherein the structural filler comprises a resin.

17. Apparatus according to claim 16, wherein the resin is a polyester resin.

18. Apparatus according to claim 16 or 17, wherein the resin comprises a solid filler.

19. Apparatus according to claim 18, wherein the solid filler is present in an amount sufficient to reduce the peak curing temperature of the resin.

20. Apparatus according to either of claims 18 or 19, where the solid filler comprises from 10 to 70% by weight of the structural filler.

21. Apparatus according to claim 20, wherein the solid filler comprises from 20 to 60% by weight of the structural filler.

22. Apparatus according to any of claims 18 to 21, wherein the solid filler is a finely powdered chalk.

23. Apparatus according to any preceding claim, wherein at least one of the inner housing or the outer housing comprises a fibre-reinforced matrix comprising one or more fibres extending helically with respect to the longitudinal axis of the apparatus, each fibre extending at an angle of from 25° to 85° to the longitudinal axis of the apparatus.

24. Apparatus for providing an enclosure in locations of elevated pressure, the apparatus comprising:

an inner housing comprising an inner housing body and two opposing inner housing ends;

an outer housing comprising an outer housing body and two opposing outer housing ends;

the inner housing being disposed fully within the outer housing, the inner and outer housings defining an annular cavity therebetween; and

a structural filler within the cavity extending between the outer housing and the inner housing;

at least one of the inner housing or the outer housing comprising a fibre-reinforced matrix comprising one or more fibres extending helically with respect to the longitudinal axis of the apparatus, each fibre extending at an angle of from 25° to 85° to the longitudinal axis of the apparatus.

25. Apparatus according to either of claims 23 or 24, wherein each fibre extends at an angle of from 35° to 65° to the longitudinal axis of the apparatus.

26. Apparatus according to claim 25, wherein each fibre extends at an angle of from 45° to 60° to the longitudinal axis of the apparatus.

27. Apparatus according to any of claims 23 to 26, wherein the at least one of the inner housing or the outer housing comprises a plurality of layers of fibre-reinforced matrix, one of a pair of adjacent layers having one or more fibres extending at an angle of x° to the longitudinal axis and the second of the pair of adjacent layers having one or more fibres extending at an angle of 360-x° to the longitudinal axis.

28. Apparatus according to claim 27, wherein x is an angle in the range of from 45° to 65°.

29. Apparatus according to claim 28, wherein x is an angle of about 55°.

30. Apparatus according to any of claims 23 to 29, wherein both the inner housing and outer housing comprise a fibre-reinforced matrix.

31. Apparatus according to any of claims 23 to 30, wherein the fibre-reinforced matrix comprises a polyester resin.

32. Apparatus according to any of claims 23 to 31, wherein the one or more fibres of the fibre-reinforced matrix are glass fibres, carbon fibres or nylon fibres.

33. Apparatus according to any preceding claim, wherein a protective layer extends over the outer surface of the outer housing.

34. Apparatus according to claim 33, wherein the protective layer comprises a shock absorbent layer adjacent the outer surface of the outer housing.

35. Apparatus according to claim 34, wherein the shock absorbent layer comprises a foam or a honeycomb material.

36. Apparatus according to any of claims 33 to 35, wherein the protective layer comprises a rigid outer layer.

37. Apparatus according to claim 36, wherein the rigid outer layer comprises fibre-reinforced plastic or metal.

38. Apparatus according to claim 37, wherein the outer layer comprises metal, which metal is in the form of one or more strips wound around the outer surface of the apparatus.

39. Apparatus according to claim 38, wherein the one or more metal strips extend helically around the outer surface of the apparatus.

40. Apparatus according to any preceding claim, wherein the apparatus comprises a third housing, the third housing defining a cavity with the adjacent inner housing or outer housing.

41. Apparatus according to any preceding claim, wherein a bulkhead is disposed within the interior of the inner housing.

42. Apparatus according to claim 41, wherein the inner housing comprises two inner housing portions connected by a joint, the bulkhead extending across the interior of the inner housing coincident with the joint.

43. Apparatus according to claim 41, wherein the joint is at the junction of an inner housing end and the inner housing body, the bulkhead being connected to the inner housing such that, in the event of a leak, water entering the apparatus is caused to enter the interior of the inner housing end.

44. Apparatus according to any of claims 41 to 43, wherein the bulkhead is a compliant bulkhead, the stiffness of the bulkhead being such that differential stiffness between the bulkhead and the inner housing is reduced.

45. Apparatus according to claim 44, wherein the compliancy of the bulkhead is provided by apertures in the bulkhead.

46. A method of preparing an apparatus for providing an enclosure in locations of elevated pressure, the method comprising:

forming an inner shell;

applying a filler to the outer surface of the inner shell; and

forming an outer shell around the outer surface of the core material.

47. A method according to claim 46, wherein the inner shell is formed by winding filaments onto a mandrel.

48. A method according to claim 47, wherein the inner shell is formed by successively winding a plurality of separate layers of filaments.

49 A method according to claim 47 or 48, wherein the inner shell, once formed, is cured.

50. A method according to any of claims 46 to 49, wherein the filler is bonded to the outer surface of the inner shell.

51. A method according to any of claims 46 to 50, wherein the filler is applied as layers of filler material.

52. A method according to claim 51, wherein the filler is honeycomb, corrugated filler material, sheet polymer or balsa.

53. A method according to any of claims 46 to 50, wherein the filler is a foam.

54. A method according to any of claims 46 to 50, wherein the filler comprises one or more tubes, channels or I-beams.

55. A method according to any of claims 46 to 54, wherein the inner shell comprises an inner housing body or a portion of an inner housing body and an inner housing end.

56. A method according to any of claims 46 to 55, wherein the outer shell is formed by winding filaments onto the outer surface of the filler.

57. A method according to claim 56, wherein the outer shell is formed by successively winding a plurality of separate layers of filaments.

58. A method according to claim 56 or 57, wherein the outer shell, once formed, is cured.

59. A method of preparing an apparatus for providing an enclosure in locations of elevated pressure, the method comprising:

forming an inner shell;

forming an outer shell;

locating the inner shell concentrically within the outer shell, thereby defining a cavity between the inner and outer shells; and

filling the cavity with a filler.

60. A method according to claim 59, wherein one or both of the inner shell an the outer shell is formed by winding filaments onto a mandrel.

61. A method according to claim 60, wherein the said shell or shells is formed by successively winding a plurality of separate layers of filaments.

62. A method according to claim 60 or 61, wherein the said shell or shells, once formed, is cured.

63. A method according to any of claims 59 to 62, wherein the filler comprises a substantially void-free polymer or a foamed polymer.

64. A method according to any of claims 59 to 62, wherein the filler comprises a foamed metal.

65. A method according to any of claims 59 to 64, wherein the filler is cured after being applied in the cavity.

66. A method according to claim 65, wherein the outer surface of the inner housing and the inner surface of the outer housing are lined with a heat retardant material of sufficient thickness to protect the material of the housings from the peak curing temperature of the filler.

67. A method according to claim 66, wherein the heat retardant material is a ceramic paper or tape applied in sheets or strips to the respective surface, or is a heat retardant composition applied by spraying.

68. A method of preparing an apparatus for providing an enclosure in locations of elevated pressure, the method comprising:

forming an inner shell;

applying a filler to the outer surface of the inner shell;

forming an outer shell;

heating the outer shell to cause expansion of the outer shell

locating the inner shell and the applied filler concentrically within the outer shell; and

allowing the outer shell to cool so as to mechanically engage the filler in an interference fit.

69. A method according to claim 68, wherein one or both of the inner shell and the outer shell is formed by winding filaments onto a mandrel.

70. A method according to claim 69, wherein the said shell is formed by successively winding a plurality of separate layers of filaments.

71 A method according to claim 69 or 70, wherein the said shell, once formed, is cured.

72. A method according to any of claims 68 to 71, wherein the filler is bonded to the outer surface of the inner shell.

73. A method according to any of claims 68 to 72, wherein the filler is applied as layers of filler material.

74. A method according to claim 73, wherein the filler is honeycomb, corrugated filler material, sheet polymer or balsa.

75. A method according to any of claims 68 to 72, wherein the filler is a foam.

76. A method according to any of claims 68 to 72, wherein the filler comprises one or more tubes, channels or I-beams.

77. A method according to any of claims 68 to 76, wherein the outer diameter of the filler is adjusted after application to the outer surface of the inner housing to correspond to the inner diameter of the outer shell.

78. A method according to any of claims 68 to 77, wherein the outer shell is bonded to the filler.

79. A method according to claim 78, wherein the adhesive is cured.

80. A method according to any of claims 46 to 79, wherein one or both of the inner shell and the outer shell comprise a housing body, the method further comprising applying a housing end to each end of the or each housing body.

81. A method according to any of claims 46 to 79, wherein one or both of the inner shell and the outer shell comprise a housing body and a housing end, the method further comprising applying a second housing end to the open end of the or each housing body.

82. A method according to any of claims 46 to 79, wherein at least the inner shell comprises a housing body portion and a housing end, the method comprising preparing two such inner shells and joining the two inner shells at their open ends.

83. A method according to any of claims 46 to 82, further comprising applying a protective layer to the outer surface of the outer shell.

84. A method according to claim 83, wherein a shock absorbent layer is applied to the outer surface of the outer shell and a rigid outer layer is applied to the outer surface of the shock absorbent layer.

85. A method according to claim 84, wherein the shock absorbent layer is a honeycomb or a foam.

86. A method according to either of claims 84 or 85, wherein the rigid outer layer is one or more metal strips, which strips are wound around the outer surface of the absorbent layer.

87. A method according to claim 86, wherein the strips are wound helically about the outer surface.

88. A method of deploying a buoyancy apparatus at an underwater location where buoyancy is required, which apparatus has a fluid-tight cavity capable of accommodating a liquid, the method comprising:

ballasting the apparatus by filling the fluid-cavity with a liquid to an extent necessary to provide the appropriate level of buoyancy;

positioning the apparatus at the said location; and

withdrawing the liquid from the fluid-tight cavity.

89. A method according to claim 88, wherein the liquid is withdrawn by means of a reciprocating piston moved within a cylinder.

90. A method according to claim 89, wherein the liquid is withdrawn by repeated operations of the reciprocating piston through a cycle comprising:

movement of the piston in a first direction to draw liquid from the fluid-tight cavity into the cylinder;

movement of the piston in a second direction, opposite the first, to eject liquid from the cylinder to a location other than the fluid-tight cavity.

91. A method according to any of claims 88 to 90, wherein the liquid is water.

92. A method according to claim 91, wherein the water is ejected into the environment.

93. A system for deballasting a buoyancy apparatus, which apparatus has a fluid-tight cavity containing a liquid, the system comprising:

a cylinder;

a piston arranged for reciprocal movement within the cylinder;

a line for connection to the fluid-tight cavity of the apparatus;

a first non-return valve allowing the flow of fluid from the cavity into the cylinder; and

a second non-return valve allowing the flow of fluid from the cylinder.

94. A system according to claim 93, wherein the cylinder, piston, drive and first and second non return valves are housed together on a mobile support structure for use in the vicinity of the deployed buoyancy apparatus.

95. A system according to either of claims 93 or 94, wherein the piston is operable hydraulically.

96. A system according to any of claims 93 to 95, wherein the system further comprises a drive for the piston.

97. Apparatus for providing buoyancy at underwater locations comprising:

one or more shells enclosing a buoyancy cavity;

an integrity monitoring system comprising one or more gyroscopes arranged to detect motion of the apparatus.

98. Apparatus for providing buoyancy at underwater locations comprising:

one or more shells enclosing a buoyancy cavity;

one or more optical fibres extending within the shell; and

an interface for retrieving data from the optical fibres indicating the level of strain within the one or more shells.

99. Apparatus according to claim 98, wherein the interface is compatible with a ROV.

100. An underwater arch comprising an apparatus according to any one of claims 1 to 45 or 97 to 99 to provide buoyancy.

101. An underwater arch according to claim 100, wherein the arch is an articulated arch, an articulated truss arch, a distributed buoyancy arch, a lay-over arch or a tied-in arch.

102. An underwater arch according to either of claims 100 or 101, wherein the said apparatus is a structural member of the arch.